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Director's Office

ON SEARCHING FOR HEAVY STABLE PARTICLES

E288 Collaboration

We propose to revive E187, our previous search for heavy, long-lived particles. It is important that such a search be continued at this time for two reasons:

1) Our discovery of the upsilon family led to the conjecture that the $\Upsilon = q\bar{q}$, where q is some new quark. This new heavy quark, q, may couple in a wholly different manner to old quarks and it becomes conceivable that such objects as $q\bar{u}$ and quu, etc. are absolutely stable. Indeed this possibility has even occurred to some theorists,[1] presumably making the idea respectable.

2) The motivations of E187, based primarily on curiosity, were good enough to pass a very high level PAC. The possibility of a very large increase in sensitivity, along with the increase in incident proton energy to 400 GeV, produced a much more exciting search than in 1973, the original E187 run. Indeed, the sensitivity reached will be 100 times better than the upsilon production cross section and 10 times better than a recent theoretical estimate.[1]

5 pgs.

[1] Robert N. Cahn, Phys. Rev. Lett. 40, 80 (1978). S. Glashow, Harvard preprint. A. Salam, long series of comments on stable objects.

Sensitivity

We propose to use the Neutrino Lab beam N1 with quad triplet tuned to either positive or negative hadrons of about 75 GeV/c momentum. To calculate the acceptance of this beam we use the measured yield of 1.5 x 10^7 π^- at 225 GeV/c for 10^{13} incident protons (as measured by E444). i. e.,

$$1.5 \times 10^7 = 10^{13} \times 80 \text{ gms} \times 6 \times 10^{23} \times \frac{d\sigma}{dp\,d\Omega}(\pi^-, x=0.56) \times \Delta\Omega \times \Delta p \quad (1)$$

now from the E21 measurement of pion yields at 400 GeV we get

$$\frac{d\sigma\,(\pi^-, x = 0.56)}{dp\,d\Omega} = 31 \text{ mb/GeV/sr}. \quad (2)$$

From (1) and (2),

$$\begin{aligned}(\Delta\Omega \times \Delta p) &= 1 \times 10^{-6} \text{ at } 225 \text{ GeV}\\ &= 0.33 \times 10^{-6} \text{ at } 75 \text{ GeV}.\end{aligned}$$

We choose 75 GeV since an object of mass 5 GeV produced at $y = 0$ and $p_T = 0$ in the center-of-mass has a lab momentum of 75 GeV.

In one good days run we should be able to get $\approx 10^4$ pulses x 10^{13} protons = 10^{17} protons. Therefore one heavy stable particle detected corresponds to a cross section of:

$$\begin{aligned}\frac{d\sigma}{dp\,d\Omega} &= \frac{1}{10^{17} \times 80 \text{ gms} \times 6 \times 10^{23} \times 0.33 \times 10^{-6}} \quad (3)\\ &= 6 \times 10^{-37} \text{ cm}^2/\text{GeV/sr}.\end{aligned}$$

Our observed cross section for Υ production is[2]

$$B \times \left(E\frac{d^3\sigma}{dp^3}\right) \approx 5 \times 10^{-38}\ \mathrm{cm}^2/\mathrm{GeV}^2$$

B is the branching ratio $\Upsilon \rightarrow \mu^+\mu^-$.

Since

$$\frac{d\sigma}{dp\,d\Omega} = p^2\frac{d^3\sigma}{dp^3} \approx p\left(E\frac{d^3\sigma}{dp^3}\right)$$

$$\therefore\ B\frac{d\sigma(\Upsilon)}{dp\,d\Omega} = (75\ \mathrm{GeV})\ (5 \times 10^{-38}) = 3.8 \times 10^{-36}\ \mathrm{cm}^2/\mathrm{GeV/sr}.$$

Most theoretical predictions of the dilepton branching ratio of the Υ place it at about 5%.

$$\therefore\ \frac{d\sigma(\Upsilon)}{dp\,d\Omega} = 10^{-34}\ \mathrm{cm}^2/\mathrm{GeV/sr}.$$

This is to be compared with the limit of 10^{-31} cm^2 for stable charged particles quoted in E187 and the limit of 5×10^{-34} cm^2 quoted by Gustafson et al.[3] in E330, a stable neutral particle search.

Our sensitivity, Eq. (3), is better than 1/100 of the Υ production cross section per day.

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[2] D. M. Kaplan et al., Fermilab publication.

[3] H. R. Gustafson et al., Phys. Rev. Lett. 37, 474 (1976).

Technique

As in E187, time-of-flight over the 1 km flight path of the N1 beam combined with the momentum analysis of the beam determined the mass. A confirmation of the mass and a rejection of the copious flux of light hadrons is provided by differential Cerenkov counters.

An M = 5 GeV, p = 75 GeV, object has a flight time to the muon lab 7.5 nsec longer than a pion. A time gate from 4 nsec to 14 nsec after the arrival time of light hadrons is sensitive to masses from 4 to 7 GeV. It is also possible to tune a 5 atm freon Cerenkov counter to reject light at the largest angles coming from $\beta > 0.999$ particles. This Cerenkov counter will not be sensitive to pions, kaons and protons but will be fully efficient for heavier particles up to a 7 GeV threshold. It appears that the Cerenkov counters built for E75, Quark Search, will do the job perfectly. They are presently residing unused in the neutrino area and will require only small modifications.

We also need some simple veto counters around the beam pipe and a few beam scintillators. The rf signal from the accelerator is timed against the outputs of the two differential Cerenkov counters. The rf signal exists in the experimental areas already. The electronics needed is very simple and can be borrowed from the E288 stock or used in place in the Muon Spectrometer Facility Portakamp; we envision recording the data on the 2-dim. PHA used in E75.

Manpower

E288 runs smoothly with one man shifts. We are sufficiently excited by the stable particle search possibility that we will find the time to assemble and run E187. A one-week test run to study the N1 beam, rf structure, and general environment in the muon area, followed by a weekend run should reach the sensitivities claimed.

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for E288 Collaboration